JRTE | Vol. 45, No. 4, pp. 339–360 | ©2013 ISTE | iste.org/jrte

Examining Domains of Technological Pedagogical Content Knowledge Using Factor Analysis

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Abstract

This study examined the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology through an exploratory factor analysis using responses from 365 preservice teachers enrolled in an educational technology course in the United States. The participants were completing methods courses and field experience concurrent to the educational technology course, allowing them to contextualize the content they learned during the semester. The survey, grounded in the framework of Technological Pedagogical Content Knowledge (TPACK), is designed to measure seven domains associated with technological, pedagogical, and content knowledge. Although the influence of the TPACK framework on teacher education programs continues to grow, research indicates the need for clearer distinctions between the domains. Results from this study revealed that participants did not always make conceptual distinctions between the TPACK domains. Specifically, factors were congruent across only technological knowledge (TK) and content knowledge (CK) and not congruent across pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and TPACK. Additionally, PK and PCK loaded together, indicating the participants did not distinguish PK from PCK. Overall, this study confirms the need to provide more clarity about the TPACK framework and to revisit survey instruments built directly around the framework. (Keywords: TPACK, survey, factor analysis, preservice teachers, teacher education)

The adoption of novel and rapidly evolving technologies within schools has placed new demands on classroom teachers, who must learn to use new tools and develop technology-integrated lessons that support the development of students' 21st century skills (Hutchison & Reinking, 2011). These demands have been intensified by the implementation of increasingly rigorous standards that include attention to the use of new technologies and a shift toward computer-based testing (Common Core State Standards Initiative, 2010). As a result, novice teachers must enter the classroom with the knowledge and skills necessary to plan and teach pedagogically sound, technology-integrated, standards-based lessons (Lawless & Pellegrino, 2007).

To address teacher preparation in the use of technology, researchers and teacher educators have increasingly looked to the theoretical framework of Technological Pedagogical Content Knowledge (TPACK), which is used to describe what teachers need to know to effectively integrate technology into their teaching practice (Mishra & Koehler, 2006). Building upon Shulman's (1986) notion of content-specific knowledge for teaching or pedagogical content knowledge (PCK), TPACK centers on the nuanced interactions among three bodies of knowledge: content, pedagogy, and technology (Koehler & Mishra, 2008). Since its inception, the TPACK framework has been at the center of efforts to inform and transform teacher preparation programs (Abbitt, 2011; Chai, Koh, & Tsai, 2010; Harris & Hofer, 2009).

Although the TPACK framework is useful for conceptualizing teacher learning, current theorizing has questioned its construct validity and applicability (Angeli & Valanides, 2009; Archambault & Barnett, 2010). Cox and Graham (2009) and Graham (2011), for example, acknowledged difficulty in distinguishing the boundaries between different knowledge components, likely due to lack of clarity around the constructs within the TPACK framework. Similarly, Angeli and Valanides (2009) argued that the "the explanations of technological pedagogical content knowledge and its associated constructs that have been provided are not clear enough for researchers to agree on what is and is not an example of each construct" (p.60).

The difficulty in providing precise definitions of TPACK constructs is problematic in efforts to address the effectiveness of teacher preparation and professional development programs because it makes it difficult to create robust instruments for conveniently measuring and assessing TPACK in a variety of contexts (Albion, Jamieson-Proctor, & Finger, 2010; Graham, 2011).

The most promising self-report instrument designed to date is the Survey of Preservice Teachers' Knowledge of Teaching and Technology, which employed the use of TPACK as a guiding framework (Schmidt, Baran, Thompson, Mishra, Koehler, & Shin, 2009). This instrument has generated much promise in the literature because of its efficiency and high internal consistency reliability (Abbitt, 2011). Recent studies, however, have questioned the construct validity of the instrument, and by extension, the TPACK framework (e.g., Chai et al., 2010). The purpose of this work is to more closely examine the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology through an exploratory factor analysis using a sample of preservice teachers in the United States. Findings of the study can help illuminate whether technology, content, and pedagogy blend together to form the distinctive constructs described by the TPACK framework. They also have implications for future research and practice, including the design of more robust survey instruments, and for providing further clarity about the TPACK framework.

The TPACK Framework

TPACK is a theoretical framework that describes the relationships between technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK; Mishra & Koehler, 2006). The TPACK framework is grounded in the work of Lee Shulman (1986), whose theory regarding the relationship between CK and PK has informed much of the recent research in the field of teacher education (Shulman & Shulman, 2007). In response to the emergence of new technologies and the need to prepare preservice teachers to use sophisticated tools and technologies designed for the classroom, Mishra and Koehler (2006) extended Shulman's theory to include TK. Specifically, TPACK provides a framework for understanding the practitioner knowledge needed for effective technology integration, particularly at the intersection between PK and CK. Researchers interested in preparing preservice and inservice teachers to deliver pedagogically sound, technology-integrated instruction are increasingly looking to the TPACK framework to provide theoretical support for their work (e.g., Harris, Mishra, & Koehler, 2009; Mouza, 2011).

More specifically, the TPACK framework describes seven knowledge domains needed for effective technology integration, as illustrated in Figure 1 (p. 342; Mishra & Koehler, 2006). TK refers to preservice teachers' knowledge and proficiency with technology tools. CK refers to subject-matter knowledge and the ability to identify content-specific learning goals. PK refers to the theoretical and methodological knowledge needed to develop appropriate instruction. These domains combine to form four additional constructs. Technological content knowledge (TCK) refers to the reciprocal relationship between technology and content, the understanding that technology tools can be used to support content-specific learning goals. The relationship between pedagogy and content, or PCK, refers to the practitioner knowledge needed to develop and deliver effective content-specific instruction. Technological pedagogical knowledge (TPK) relates to the understanding of how technology can influence teaching and learning. When technology, content, and pedagogy blend together effectively, the result is TPACK—a unique body of knowledge that supports a teacher's ability to situate TK within CK and PK to develop effective technology-integrated lessons (Harris et al., 2009).

Examining TPACK in Practice Using Qualitative Approaches

Increasingly, the TPACK framework informs the field of teacher education, fueling a flurry of research efforts reporting on the development and assessment of TPACK (Archambault & Barnett, 2010; Archambault & Crippen, 2009; Chai et al., 2010). Much of this work has aimed at providing empirical support for the TPACK framework and validating assessment strategies and instruments used to measure TPACK (e.g., Chai et al., 2010).

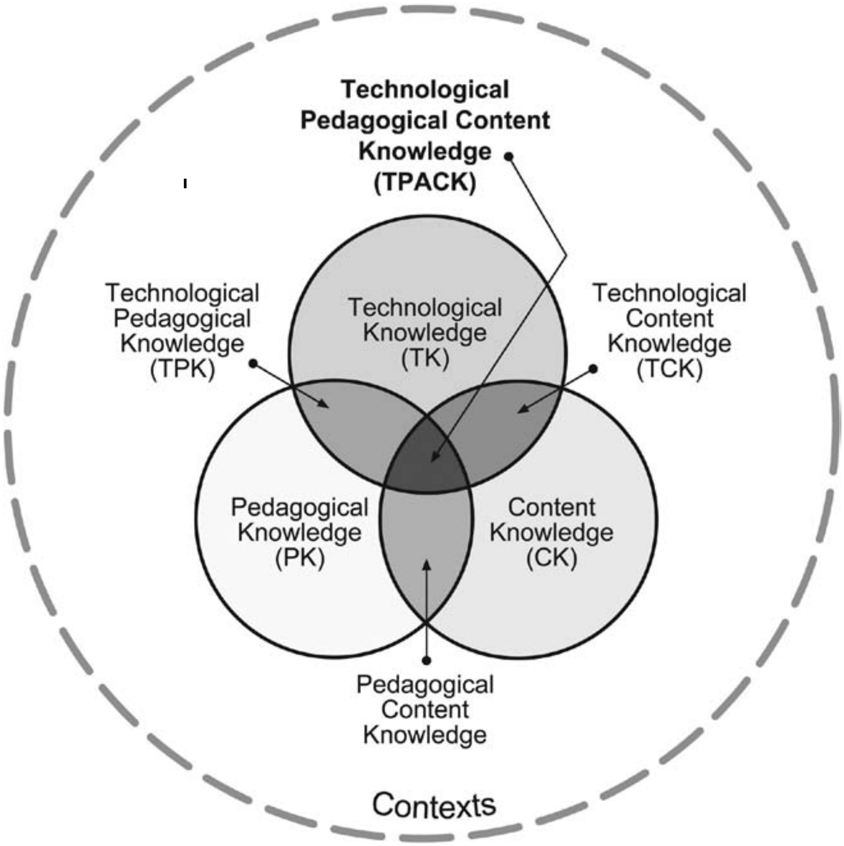

Figure 1. TPACK Framework (http://tpack.org).

In an effort to summarize this body of work, Voogt, Pareja Roblin, and van Braak (2012) conducted a systematic review of TPACK literature published between 2005 and 2011 that included 55 peer-reviewed journal articles. The purpose of the review was to investigate the theoretical basis and practical use of TPACK. Findings demonstrated different understandings of TPACK and of TK, which in turn influenced the way TPACK was measured across studies.

Earlier attempts to measure TPACK have frequently used qualitative methods that focused on the examination of collaborative conversations, teacher lesson plans, case narratives, and other performance assessments (e.g., Angeli & Valanides, 2009; Harris, Grandgenett, & Hofer, 2010; Koehler, Mishra, & Yahya, 2007; Mouza & Wong, 2009). The earliest attempt to measure TPACK has been described by Koehler et al. (2007), who employed discourse analysis to examine conversations between graduate students and faculty who had to design online courses through the period of one semester. Their analysis looked at how TPACK elements were represented in team conversations at two different points in time. The study indicated that over time, the initially separate topics of technology, content, and pedagogy became more strongly interconnected.

Instead of analyzing conversations, Mouza and colleagues (see Mouza & Karchmer-Klein, 2013; Mouza, 2011; Mouza & Wong, 2009) looked for evidence of TPACK and TPACK-associated constructs (i.e., PK, CK, PCK, TK, TPK, & TCK) in preservice and inservice teachers' reflective case narratives reporting on the implementation of technology-integrated lessons in authentic classroom situations. Similarly, Angeli and Valanides (2009) and Graham et al. (2011) looked for evidence of TPACK (or ICT-TPCK, as Angeli & Valanides call it) in preservice teachers' design tasks. Specifically, Angeli and Valanides (2009) assessed teachers' performance on different design tasks using expert assessment, peer assessment, and self-assessment with five criteria: identification of suitable topics, appropriate representations to transform content, identification of teaching strategies difficult to implement by traditional means, selection of appropriate tools and their pedagogical uses, and identification of appropriate integration strategies. Along the same line of work, Graham et al. (2011) examined how preservice teachers make decisions about the use of technology in their teaching by analyzing three teaching design tasks during a pre- and post-treatment assessment. In their analysis, Graham et al. used TPACK as a conceptual lens and identified themes from preservice teachers' rationales that mapped to the TPACK constructs.

Trying to streamline TPACK assessment in teacher artifacts, Harris et al. (2010) developed and tested the TPACK-based Technology Integration Assessment Rubric. The rubric can be used to evaluate preservice teachers' lesson-plan documents and other planning artifacts by looking at demonstrated TPK, TCK, and TPACK along with the "fit" of selected content, teaching strategies, and technologies considered together. The rubric was found to be reliable, although no efforts have been made to test it with inservice teachers' artifacts.

This corpus of qualitative work is important because it demonstrates what TPACK looks like in practice and not merely at a theoretical level. Yet these approaches are time consuming for researchers and participants, thereby making them difficult to implement with large groups of teachers in a quick, efficient, and reliable way (Albion et al., 2010).

Examining TPACK in Practice Using Survey Instruments

Due to the wide use of the TPACK framework in teacher education, it is necessary to develop valid and reliable instruments that can measure TPACK and related TPACK constructs (Archambault & Barnett, 2010; Archambault & Crippen, 2009; Chai et al., 2010). According to Schmidt et al. (2009), "using TPACK as a framework for measuring teaching knowledge could potentially have an impact on the type of training and professional development experiences that are designed for both preservice and inservice teachers" (p.125). To date, however, only two mature instruments have been developed, one targeting inservice online teachers (Archambault & Crippen, 2009) and the other targeting preservice teachers (Schmidt et al., 2009).

Archambault and Crippen (2009) have developed a survey instrument including 24 items designed to measure online teachers' knowledge. The instrument employed the use of TPACK as a guiding framework. In particular, the researchers wrote items based on definitions provided by Koehler and Mishra (2005) and Shulman (1986). Following content validity testing and extensive piloting, they administered the survey to 596 online teachers. Factor analysis using varimax rotation with the 24 items included in the survey revealed that only three noteworthy factors emerged within the survey, rather than the seven suggested by the TPACK framework. Specifically, participants reported the existence of PCK, TCK, and TK. Further, the only clear domain that distinguished itself was that of technology.

Similarly, Schmidt et al. (2009) developed and validated the Survey of Preservice Teachers' Knowledge of Teaching and Technology, which is designed to measure preservice teachers' self-assessment of their TPACK. The survey is also grounded in the TPACK framework as proposed by Mishra and Koehler (2006) and is designed to measure the seven domains of technological, pedagogical, and content knowledge illustrated in Figure 1. The survey extends to general contexts, multiple content areas, and multiple approaches to professional development. Yet it is specifically designed for preservice teachers majoring in elementary or early childhood education and is focused on the content areas they will be teaching in their future classrooms.

The development of the survey progressed through various stages, whereby the authors first reviewed other pilot instruments reported in the literature and solicited feedback from content experts. Based on that feedback, the authors constructed a 75-item survey and administered it to a group of 124 preservice teachers. Subsequently, the authors examined construct validity for each knowledge domain using factor analysis. Given the small sample size, however, they performed factor analysis on the items within each subscale rather than on the entire instrument. Based on this analysis, they identified problematic issues and revised or eliminated individual items. This resulted in a revised instrument that included 47 items. They then repeated reliability statistics with each knowledge domain, and results demonstrated high levels of internal consistency reliability.

Using a modified version of the survey instrument developed by Schmidt and colleagues (2009), Chai et al. (2010) examined TPACK development with a sample of 889 preservice teachers enrolled in a postgraduate teacher preparation program in Singapore. Their instrument included 18 modified items specific to the experiences of preservice teachers in Singapore. Analysis revealed a four-factor model—including TK, PK, CK, and TPACK—rather than the seven domains identified by TPACK theorists and validated by Schmidt and colleagues (2009).

Similarly, Koh, Chai, and Tsai (2010), used a modified version of the survey developed by Schmidt et al. (2009) to examine its construct validity through an exploratory factor analysis of a large sample of preservice teachers in Singapore. Results demonstrated that participants had difficulty distinguishing between general PK and PCK, and therefore the authors relabeled those items as *knowledge of pedagogy*. Likewise, participants had difficulty distinguishing among TPK, TCK, and TPACK, so they relabeled those items as *knowledge of teaching with technology*. Overall, this work also failed to support the seven constructs as described in the TPACK framework.

Differences in populations and survey design aside, these studies suggest the need for additional research examining the TPACK survey developed by Schmidt et al. (2009). Interestingly, both studies that used the survey were conducted outside the United States and used modified versions of the instrument. As the survey was developed in the context of teacher education programs in the United States, it is possible that it is not responsive to the experiences of preservice teachers in Singapore or countries with different types of teacher education programs. The lack of further empirical research with a U.S. population of preservice teachers, in combination with contradictory findings reported in the literature, indicate the need for additional studies in this area.

Purpose of the Study

Empirical support for a theoretical framework currently used to inform the development of preservice teachers' knowledge is vital, given the important implications for teacher preparation programs. Yet studies reporting on exploratory factors analyses have not confirmed the seven-domain model supported by the TPACK framework (Voogt et al., 2012). Research examining the TPACK domains as described by Schmidt et al. (2009) using factor analyses (Archambault & Crippen, 2009) is, therefore, necessary to inform theory and practice. This study aims to address this research gap by examining the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology through an exploratory factor analysis using responses from 365 preservice teachers in the United States. Specifically, the study was framed by the following research question: What do the responses of preservice teachers to the Survey of Preservice Teachers' Knowledge of Teaching and Technology reveal about the domains of TPACK?

Methods

Context

The study was conducted in the context of an undergraduate teacher education program in a mid-Atlantic university in the United States. We collected data at the conclusion of a required educational technology course typically taken by juniors and seniors. The course, titled Integrating Technology in Education, runs every semester (fall and spring) for 15 weeks. While completing the course, participants are also enrolled in methods courses in literacy and social studies, science, and/or mathematics. Additionally, they are placed in elementary or middle school field placements, where they work with a cooperating teacher for a period of 3 weeks throughout the semester (one week early in the semester, one week in the middle of the semester, and one week toward the end of the semester).

The purpose of the course is to introduce prospective teachers to technologies available for use in classroom content areas (e.g., concept-mapping software, interactive manipulatives, Internet resources, and Web 2.0 tools) and to model a variety of ways that technologies can be used to support learning. The course is taught in a computer laboratory to facilitate easy access to technology and hands-on learning experiences. Although the course helps prospective teachers improve their technological literacy, it places emphasis on the interactions among technology, content, and pedagogy. For example, participants are explicitly introduced to the TPACK framework as a means for designing curriculum-based, technology-integrated lessons. Further, course projects and assignments enable participants to explore different tools and design lessons that demonstrate ways that they can use technology in conjunction with content and pedagogy to support student learning. In designing lesson plans, participants use the TPACK framework as a guide; they decide the learning goals to be addressed, make pedagogical decisions related to the implementation of the lesson, identify specific activities that will comprise the learning experience, select assessment strategies, and, finally, choose technology tools that match their content and pedagogy (Harris & Hofer, 2009). Table 1 provides an overview of course assignments.

Sample

Participants included 365 preservice teachers enrolled in the course between fall 2009 and fall 2011. Although multiple sections of the course were taught every semester, all sections were taught by the same full-time faculty (the third and fourth authors). All sections used the same syllabus and course activities; instructors remained in close contact throughout the period of the study, thus ensuring consistency in instruction across all sections of the course.

Of the 365 preservice teachers who participated in the study, a majority of the participants were female (96%). All were juniors (60%) or seniors (40%) enrolled in a teacher preparation program. During their participation in the course, all participants were enrolled in a field experience at a local elementary (K–5) or middle school (6–8); 47% of the participants had previously completed another field experience.

Table 1. Description of Course Assignments

Title	Description
Integrated Lesson Review	Participants identify a technology integrated lesson in a content area of their choice from a lesson-plan portal called Thinkfinity. Subsequently, they prepare a critique that discusses the instructional objectives of the lesson, the strengths and weaknesses of the learning activities presented in the lesson, the content and technology standards addressed, and the role of technology in relation to the lesson's objective.
Concept Mapping	Participants practice using concept-mapping software, reflect on their experiences, and generate one lesson idea that integrates concept mapping in a content area of their interest.
Technology Inventory	During the first week in their field experience, participants construct an inventory of technological resources available in their assigned schools and classrooms. The inventory needs to identify both hardware and software resources. This assignment helps participants understand the kinds of technologies typically available in K–12 settings and where they are located (e.g., computer lab, classroom, library, etc.).
Inquiry-Based Activity	Participants learn how to design inquiry-based activities around Web-based resources (akin to a WebQuest) to reinforce or teach a literacy, social studies, mathematics, or science concept. First, participants decide the content area and specific learning goals they want students to practice (e.g., what should students know, understand, or be able to do). Second, they search for Web-based resources that support students as they learn/practice these skills. Third, they design inquiry-oriented activities that engage students with the Web resources as they learn content-specific concepts. Finally, they describe the mechanisms in which student work will be assessed.
Collaboration Tools	Participants learn about Web 2.0 tools (e.g., blogs, wikis, podcasts, Glogster, or VoiceThread). They use these tools to complete course assignments and generate lesson ideas that focus on the integration of the selected tool in a classroom setting.
Reflective Essay	In the final course assignment, participants implement one of the activities designed earlier in the course in their field placement. They can choose to implement their lessons with a whole class but often are advised to try their activities with smaller groups of students. This assignment seeks to strengthen the connection between theory and practice. Upon completing the implementation of their lesson, participants write a reflective case that discusses their experience following specific writing and reflection prompts.

Data Collection Instrument

The Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009) is a validated survey instrument designed to measure the development of preservice teachers' technological, pedagogical, and content knowledge. The survey measures participants' responses to a series of questions designed to evaluate "preservice teachers' understanding of and self-reported ability to apply the domains of TPACK throughout their teacher preparation programs and in classrooms during practicum experiences" (Schmidt et al., 2009, p. 128). The survey consists of eight questions designed to collect demographic information, 59 Likert-scale items, and six open-ended questions. In addition, space is provided for open-ended comments for each set of questions, allowing students to explain their ratings and provide illustrative examples. Likert-scale items include 47 items specific to the seven domains of TPACK (i.e., TK, CK, PK, PCK, TCK, TPK, TPACK) as well as 12 items that measure two additional categories specific to the models of TPACK preservice teachers are exposed to within the university and the schools where they are engaged in field experiences.

In this study, we exported survey data from Survey Monkey into Excel. Initial review of these data revealed that we collected 367 responses to the TPACK survey. Once we had evaluated the data, we discovered that two participants did not respond to an entire question set, and as a result we removed them from the study. We imported quantitative data for the remaining 365 participants into the Statistical Package for the Social Sciences (SPSS). We calculated means to replace missing data for the remaining participants. Next, we calculated Cronbach's (1951) coefficient alpha for the 47 items measuring TPACK using this data set and found it to be .945, which is in line with scores that Schmidt and colleagues (2009) reported, providing reasonable evidence that the internal consistency of the survey instrument is reliable (Sprinthall, 2007).

Factor Analyses

We chose exploratory factor analysis (EFA) rather than confirmatory factor analysis (CFA) to identify integral constructs underlying the items on the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009). Empirical work provides evidence that CFA may be a less desirable technique for determining the number of factors measured by a data set. For instance, MacCallum and colleagues found that specification searches in correlation matrices often do not uncover the correct population model (MacCallum, 1986; MacCallum, Roznowski, & Nowrwitz, 1992). Likewise, Gorsuch (2003) reported that EFA results nearly always replicate during first-order CFAs, whereas the reverse is not true when CFA is employed to uncover first-order factors and then used to replicate results with a second sample. Therefore, we employed EFA because of the potential for stronger structural evidence to emerge during later CFA replications (Goldberg & Velicer, 2006).

We employed principal axis factor analysis, given its relative tolerance of multivariate nonnormality and superior recovery of weak factors (Briggs & MacCallum, 2003; Cudeck, 2000; Fabrigar, Wegener, MacCallum, & Strahan, 1999). We estimated communalities through squared multiple correlations and iterated them to produce final communality estimates (Gorsuch, 2003). For both theoretical and empirical reasons, we assumed that retained factors would be correlated. Consequently, we employed a Promax rotation with k = 4 (Tataryn, Wood, & Gorsuch, 1999).

One of the more critical decisions in an EFA is to determine the correct number of factors to retain and rotate (Fabrigar et al., 1999; Tabachnick & Fidell, 1996). The most common rule is to retain factors when eigenvalues are > 1.0. This solitary criterion is the default procedure in most statistical packages. The shortcoming is that implementation of solitary criteria tends to under or overestimate the number of true latent dimensions (Gorsuch, 1983; Velicer, Eaton, & Fava, 2000; Zwick & Velicer, 1986). Accordingly, we evaluated each model against the following five rules: (a) eigenvalues

Table 2. Means and Standard Deviations: Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009)

Variable	*M*	*SD*	Variable	*M*	*SD*
TK1	3.51	.89	PK6	4.04	.63
TK2	3.99	.78	PK7	4.11	.64
TK3	3.70	.84	PCK1	4.08	.68
TK4	3.54	.94	PCK2	4.15	.58
TK5	3.49	.93	PCK3	3.96	.70
TK6	3.91	.73	PCK4	4.10	.59
TK7	3.92	.76	TCK1	3.80	.79
CKM1	4.11	.74	TCK2	3.98	.65
CKM2	4.08	.77	TCK3	3.84	.81
CKM3	4.05	.77	TCK4	4.00	.72
CKSS1	3.91	.79	TPK1	4.16	.57
CKSS2	3.85	.84	TPK2	4.21	.57
CKSS3	3.96	.76	TPK3	4.33	.65
CKS1	3.79	.79	TPK4	4.24	.62
CKS2	3.84	.76	TPK5	4.22	.59
CKS3	3.82	.77	TPACK1	3.87	.76
CKL1	4.23	.58	TPACK2	4.03	.61
CKL2	4.19	.63	TPACK3	3.90	.71
CKL3	4.20	.59	TPACK4	4.02	.63
PK1	4.29	.52	TPACK5	4.22	.55
PK2	4.27	.53	TPACK6	4.21	.56
PK3	4.27	.55	TPACK7	3.82	.81
PK4	4.38	.53	TPACK8	4.19	.56
PK5	4.38	.54			

Note: M = mean, SD = standard deviation, N = 365. All values rounded to second decimal position for convenient presentation.

greater than 1.0 (Kaiser, 1960), (b) scree (Cattell, 1966), (c) Glorfeld's (1995) extension of parallel analysis (PA; Horn, 1965), (d) minimum average parcels (MAP; Velicer, 1976), and (e) interpretability (Fabrigar et al., 1999; Gorsuch, 1983).

Results

Table 2 presents means (*M*s) and standard deviations (*SD*s) for the 47 variables submitted to the EFAs. Results from Bartlett's Test of Sphericity (Bartlett, 1954) indicated that the correlation matrix was not random (χ^2 = 13824.7; $df = 1081$; $p = .000$). The Kaiser-Meyer-Olkin (KMO; Kaiser, 1974) statistic was .905, well above the .60 minimum that Kline (1994) suggested. PA suggested that eight factors should be retained, whereas Kaiser's criterion suggested that nine factors be retained. Similarly, scree pointed to nine factors, whereas MAP indicated an eight-factor solution.

Results from several studies demonstrate that MAP and PA methods provide the two best criteria for determining the correct number of factors to accept, whereas more conventional criteria (Kaiser's criterion, scree, interpretability) lead to inaccuracies, with a likely outcome of overfactoring (Glorfeld, 1995; Velicer et al., 2000; Zwick & Velicer, 1986). As a result, we accepted the eight-factor solution in this study because MAP and PA both pointed to this solution. The eight-factor solution, versus the nine-factor solution, also satisfied requirements for simple structure in that all but one variable showed appreciable factor loadings and each variable loaded on only one factor (Field, 2005; Tabachnick & Fidell, 2007).

The rotated pattern matrix for the eight-factor solution is presented in Table 3 (pp. 352–353). We interpreted the eight factors according to the magnitude and meaning of their salient pattern coefficients. All coefficients greater than or equal to .40 were considered appreciable (Tabachnick & Fidell, 2007).

The first factor was characterized by variables specific to TPK and TPACK. Consequently, we named the first factor Technological Pedagogical Knowledge; this factor aligned with theoretical expectations espoused for the Survey of Preservice Teachers' Knowledge of Teaching and Technology. The second factor was defined by appreciable loadings from PK and PCK survey items. As a result, the factor was named Pedagogical Knowledge, and this factor also aligned with theoretical expectations for the Survey of Preservice Teachers' Knowledge of Teaching and Technology. The third factor was defined by appreciable loadings from TK items, so we therefore named it Technology Knowledge. The fourth factor was characterized by appreciable loadings from TCK and TPACK and was therefore named TPACK; this was aligned with theoretical expectations for the survey. Importantly, survey items related to TCK did not load to a single, definable factor. The remaining factors each consisted of items measuring content-specific knowledge. Thus, we named them Mathematical Content Knowledge, Science Content Knowledge, Literacy Content Knowledge, and Social Studies Content Knowledge respectively. These factors are presented in Table 4 (p. 354).

We evaluated the relative independence of scores among the scales by comparing correlations among the rotated factors. Correlations between the retained factors varied (see Table 5, p. 354). Importantly, the correlation between factor 1 (TPK) and 4 (TPACK) was highest, .638 ($r^2 = .41$), suggesting that the variables share 41% of common variance. These two dimensions, then, are essentially oblique. In addition, we used Cronbach's (1951) coefficient alpha to estimate internal-consistency reliability for the eight factors; the overall Cronbach's Alpha was .71. Reliabilities greater than .70 are recommended by leading measurement textbooks (e.g., Allen & Yen, 1979; Thorndike, 1982).

Discussion

The TPACK framework and the Survey of Preservice Teachers' Knowledge of Teaching and Technology have been extensively discussed and utilized in the literature. Recent studies, however, suggest that the TPACK framework may need further clarity to facilitate differentiation of the distinct knowledge components (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Cox & Graham, 2009). The purpose of this work was to extend this body of literature by examining the congruence of the factors across TPACK domains using the Survey of Preservice Teachers' Knowledge of Teaching and Technology. This section discusses key findings and implications of this work and offers recommendations for future research. It also discusses limitations of the study.

Key Findings

Results from exploratory factor analysis yielded eight factors similar to those reported by Schmidt et al., (2009; see Table 6, p. 355). This is in contrast to the four-factor model reported by Chai et al. (2010) and the five-factor model reported by Koh et al. (2010). It is important to note that in the current study, we administered all 47 items in the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009) to participants. In contrast, Chai and colleagues (2010) revised the survey so that they administered only 18 survey items, whereas Koh et al. (2010) administered a revised version of the survey with 29 items.

Of the 47 items we analyzed in the current study, 46 items loaded to a factor and no items loaded to more than one factor. However, results from this study revealed that the factors were congruent only across TK and content areas of CK. The factors were not congruent across PK, PCK, TCK, and TPACK. PK and PCK loaded together, indicating that preservice teachers did not distinguish separate domains of PK and PCK. This finding is of concern, given that the distinction between PK and PCK is at the heart of Shulman's (1986) original PCK framework, which serves as the foundation of TPACK. Nevertheless, it is also not surprising, given that there is debate in the literature with respect to the domains that make up PCK and the blurry borders between PCK and CK (Gess-Newsome, 2002; Lee & Luft, 2008). Similar findings were reported by Chai et al. (2010), Lee and Tsai (2010), and Pamuk (2011) in studies with samples of teachers in Singapore, Taiwan, and Turkey, respectively. These authors have maintained that preservice teachers' lack of teaching experience may prevent them from distinguishing between PK and PCK and from effectively using or integrating technology into teaching, thus confounding efforts to measure the discrete domains of TPACK.

Findings also indicated that three TPACK items loaded with TPK, while the remaining items loaded with TCK, resulting in the elimination of TCK as a discrete domain. This finding is consistent with an emerging body of literature that indicates teachers' difficulty with conceptualizing TCK as a distinct knowledge domain (e.g., Hofer & Harris, 2012). Reviewing a range of studies on experienced teachers' TCK and TPK, Hofer and Harris (2012) concluded that teachers' TPK is documented considerably more often than their TCK. Similarly, examining TPACK among a sample of 1,185 preservice teachers in Singapore, Koh et al. (2010) found that participants were unable

Table 3. Rotated Pattern Matrix: Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009)

	Component							
Variable	I	II	III	IV	V	VI	VII	VIII
TPK4	.87							
TPK5	.83							
TPK3	.80							
TPACK6	.71							
TPACK8	.71							
TPK2	.66							
TPACK5	.60							
TPK1	.59							
PK3		.86						
PK2		.82						
PK5		.73						
PK6		.70						
PK4		.70						
PCK2		.69						
PCK1		.62						
PK1		.62						
PK7		.62						
PCK4		.59						
PCK3		.51						
TK2			.80					
TK3			.84					
TK6			.80					
TK4			.80					
TK1			.79					
TK5			.76					
TK7			.57					

Variable	Component I	II	III	IV	V	VI	VII	VIII
TPACK3				.80				
TCK3				.76				
TPACK4				.75				
TCK4				.68				
TCK2				.62				
TPACK1				.58				
TPACK2				.58				
TCK1				.57				
TPACK7								
CKM2					.92			
CKM3					.89			
CKM1					.87			
CKS2						.87		
CKS3						.84		
CKS1						.81		
CKL2							.92	
CKL3							.92	
CKL1							.85	
CKSS2								.93
CKSS1								.87
CKSS3								.93
Eigenvalue	14.91	4.11	3.60	2.65	2.46	2.12	1.82	1.49
% of var.	31.7%	8.7%	7.6%	5.6%	5.2%	4.5%	3.8%	3.2%
cum. % of var.	31.7%	40.5%	48.1%	53.8%	59%	63.5%	67.3%	70.5%

Note. N = 365. Pattern coefficients greater than or equal to .399 are considered salient. Interpretation was simplified through the presentation of only salient coefficients. All coefficients rounded to second decimal position for convenient presentation.

Table 4. Factors: Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009)

Component	Factor	Abbreviation	Survey Items
I	Technological Pedagogical Knowledge	TPK	TPK 1, 2 3, 4, 5; TPACK 5, 6, 8
II	Pedagogical Knowledge	PK	PK 1, 2, 3, 4, 5, 6, 7; PCK 1, 2, 3, 4
III	Technology Knowledge	TK	TK 1, 2, 3, 4, 5, 6, 7
IV	Technological Pedagogical and Content Knowledge	TPACK	TCK 1, 2, 3, 4; TPACK 1, 2, 3, 4
V	Mathematical Content Knowledge	CKM	CKM 1, 2, 3
VI	Science Content Knowledge	CKS	CKS 1, 2, 3
VII	Literacy Content Knowledge	CKL	CKL 1, 2, 3
VIII	Social Studies Content Knowledge	CKSS	CKSS 1, 2, 3

Note. Survey Item TPACK 7 did not load on any factor.

Table 5. Factor Correlation Matrix

	Component							
Variable	I	II	III	IV	V	VI	VII	VIII
I	1.00	.531	.459	.638	.149	.204	.296	.117
II	.531	1.00	.316	.561	.300	.346	.291	.236
III	.459	.316	1.00	.453	.256	.216	.130	-.006
IV	.638	.561	.453	1.00	.309	.329	272	.176
V	.149	.300	.256	.309	1.00	.294	-.036	-.153
VI	.204	.346	.216	.329	.294	1.00	.041	.078
VII	.296	.291	.130	.272	-.036	.041	1.00	.275
VIII	.117	.2367	-.006	.176	-.153	.078	.275	1.00

Note. N = 365. Extraction Method: Principal Axis Factoring; Rotation Method: Promax with Kaiser Normalization

to make conceptual distinctions between TPACK constructs such as TCK and TPK. The last TPACK item on the survey, "I can choose technologies that enhance the content for a lesson," did not load on any factor and should, perhaps, be removed from the survey.

In all, analysis from this sample of preservice teachers did not confirm factor analyses findings reported by Schmidt et al. (2009). Although this may be related to the small size of the sample used by Schmidt and colleagues (2009) or to issues specific to teacher knowledge (Chai, et al., 2010), results of this study suggest that the Survey of Preservice Teachers' Knowledge of Teaching and Technology may need to be revised based on an expanded understanding of the domains of TPACK.

Limitations

Although findings of the current study have important implications for research and teacher education, it is important to discuss the limitations. As

Table 6. Comparisons: Factor Analyses of Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009)

Study	Sample Size	# Survey Items	# Factors	Names of Factors
Chai et al. (2010)	Pre-course = 439 Post-course = 365	18 of 18 items	4	TK, CK, PK, TPACK
Koh et al. (2010)	*N* = 1185	28 of 29 items	5	TK, CK, KP, KTT, KCR
Schmidt et al. (2009)	*N* = 124	47 of 75 items	7	TK, PK, CK, PCK, TCK, TPK, TPACK
Current study	*N* = 365	46 of 47 items	8	TK, PK, CKM, CKS, CKL, CKSS, TPK, TPACK

Archambault and Crippen (2009) note, one of the important implications of research using this survey is that it is a self-report measure. To reduce potential bias, participants completed the survey online outside of class time. Yet self-report measures are subject to bias that may be difficult to control. Obtaining preservice teachers' explanations of their experiences with and interpretation of the items may help determine why different factor structures tend to load together.

Implications and Recommendations for Future Research

Preservice teachers' difficulty conceptualizing specific knowledge domains suggests the need to (a) develop more concrete definitions of the constructs that comprise the TPACK framework, including reconsidering the necessity of individual TPACK constructs; and (b) design more precise survey items that measure those constructs. Yet researchers have struggled to clearly articulate the boundaries between the constructs in the TPACK framework and offer consistent definitions for each knowledge domain (Cox, 2008; Hofer & Harris, 2012). In a conceptual analysis of the TPACK framework, for example, Cox (2008) identified 10 definitions of TCK reported in the literature. These different conceptualizations of TCK undoubtedly lead to inconsistencies in research findings (Hofer & Harris, 2012). More concrete and applied definitions of TPACK constructs will help develop more consistent and precise survey instruments. Such instruments might also consider including content-specific items related to TCK and TPACK to emphasize the content-specific nature of technology integration highlighted by the TPACK framework.

In terms of future research, it is therefore necessary to develop more concrete and applied definitions of TPACK constructs, both at the conceptual and practical level. As Graham (2011) points out, a fruitful direction of future research might begin by examining the constructs of TK, TPK, and TPACK, which are of particular importance to researchers in educational technology because they mark a distinctive move from general technology integration (TPK) to content-specific technology integration (TPACK). Modeling use of technology within content-specific areas and shifting attention to "what to teach with technology" rather than simply "how to teach" might be one way of helping preservice teachers understand the content-specific nature of TPACK (Hofer & Harris, 2012).

Future research might also look at the relative value of the different TPACK subconstructs as well as prior teaching experience. Discussing the concept of PCK within the context of science teaching, for example, van Driel, Verloop, and de Vos (1998) identified teaching experience as the major source of PCK. Similarly, other researchers also emphasized the critical importance of teaching experience in the development of PCK (e.g., Nilsson, 2008). In the field of educational technology, Harris (2008) also suggested that well-developed TPACK might be positively correlated with general teaching expertise. If this assumption becomes warranted, then it necessitates different approaches to developing TPACK among inservice teachers with significant teaching experiences and preservice teachers who often lack such experiences. In the latter case, it might be important to prioritize PCK development prior to adding technology into the mix (Pamuk, 2011). It might also be more appropriate to refer to a "developing" or "transitional" TPACK among preservice teachers. Similarly, future research might examine the comparative value of CK and TK in the development of TPACK and the extent to which strong CK or TK predicts TPACK development. Findings from such studies will point to different paths that can be taken to develop TPACK among different populations of teachers. In the current study, we examine the extent to which TK, PK, and CK—the three domains that account for the majority of TPACK in factor analysis—predict TPACK development among preservice teachers enrolled in the required educational technology course described in this study.

Finally, future research might also consider examining TPACK from a transformative perspective. The transformative perspective treats TPACK as a unique and synthesized body of knowledge that goes beyond the sum of its parts (Gess-Newsome, 2002). Much of the survey work conducted to date has followed an integrative perspective in which TPACK is treated as the combination of different knowledge constructs (Graham, 2011). This body of work, including the study reported in this manuscript, has failed to establish a satisfactory acceptable level of discriminant validity for the TPACK constructs (Archambault & Barnett, 2010; Archambault & Crippen, 2009; Burgoyne, 2010). A transformative perspective to measuring TPACK will not require that researchers measure all the knowledge subconstructs, but rather identify items that capture TPACK as a unique knowledge base.

Conclusion

This study reported on the construct validity of the Survey of Preservice Teachers' Knowledge of Teaching and Technology through an exploratory factor analysis using a large sample of preservice teachers in the United States. Findings indicated that this sample of preservice teachers did not confirm factor analyses findings reported in the work of Schmidt et al. (2009). Results of the study point to the need to revisit the TPACK framework and its associated domains as well as survey instruments built directly around the TPACK framework. Results also point to fruitful directions for future research, including more concrete and applied definitions of TPACK, the relative value of the different TPACK constructs and prior teaching experience, and the possibility of adopting a transformative perspective to the examination of TPACK as a unique knowledge body that is more than the sum of its parts.

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Manuscript received June 22, 2012 | Initial decision October 30, 2012 | Revised manuscript accepted December 9, 2012